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Non-invasive methods for estimating brain network latencies

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Abstract:

Temporal latencies between constituent parts of any complex dynamical system are an important factor in determining its function and stability. This is the case in neural systems where precise timing of the arrival of neural spikes and signals that propagate along axons is of fundamental importance. While there is a great effort today in reconstructing brain connectivity maps, there is no reliable framework to determine latencies in such networks. To address this, we use a multi-modality approach, combining structural and functional networks, each with their own latency estimates. Using structural information obtained with Mean Apparent Propagator (MAP) MRI data, we estimate the conduction velocity distribution (CVD) from the measured axon diameter distribution (AAD) in white matter. Using functional information derived from transcranial magnetic stimulation (TMS) evoked potentials (EP) via electroencephalography (EEG), as well as time-series analysis of magnetoencephalography (MEG) and electroencephalography (EEG) recordings, we have an independent assessment of the functional brain network connectivity. In deriving the latency from such data it is important to distinguish between temporal delays between neural events and true latencies that we aim to reconstruct. Latencies obtained from time-series analysis can only establish Wiener-Granger causality while incorporating TMS measurements and structural information about axons morphology and white matter path lengths provide additional information that can aid in deducing the true causality. In this abstract, we present preliminary results, with a focus on theoretical aspects and simulations. Our goal here is two-fold: 1) to improve the estimation of latencies from neural recordings using both stationary and non-stationary time-series approaches, and 2) to develop approaches that combine results from different imaging modalities, e.g., diffusion MRI and fMRI. In 1), we compare

existing analytical methods that utilize similarity and statistical dependence measures (cross-correlation, transfer entropy, etc.) on time-series, as well as our proposed approach, that is based on non-stationary features of time-series. We test all the approaches using simulations on four types of models: a) linear delay, b) multivariate autoregressive model, c) coupled non-linear dynamical systems, and d) brain network simulations based on known connectivity. We also apply and compare all the methods considered to MEG recordings (resting state with eyes closed). In 2) we use diffusion MRI-derived latency distributions as priors in a Bayesian framework combining the results from different modalities.

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